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Heat and Water Vapor Transmission Apparatus for Insulated Panels

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DETROIT

AN APPARATUS designed for measuring water vapor permeances of insulated panels has recently been developed by H. E. Robinson, F. J. Powlitch, M. A. Barron, and P. R. Achenbach of the National Bureau of Standards. Designed and constructed at the request of the Office of the Quartermaster General, Department of Defense, the apparatus will be used to obtain practical criteria for designing refrigeration warehouse panels which are not subject to damage due to internal condensation of moisture. Elimination of condensation and water accumulation would not only result in better control of temperatures but would prevent rapid deterioration of the panels due to decay or corrosion of their components or fasteners.

Essentially the apparatus consists of two parts coupled together to form a large, well-insulated enclosure. The test panel, 4 by 8 ft, is installed in one section against a gasketed stop in such a way that, when the apparatus is closed, it divides the enclosure into a warm side and a cold side.

Both sections are constructed using 2- by 4-in. softwood framing with $\frac{1}{4}$ -in. plywood glued and screwed to its inner and outer faces. Framing was kept to a minimum consistent with structural requirements to reduce heat conduction through framing members. The spaces between the plywood sheets are filled with slightly compressed layers of 2-in. low-density glass fiber thermal insulation. Both sections are also lined on the inside and covered on the outside with 0.006-in.

aluminum sheet for vapor proofing. However, heavy polyethylene sheet is substituted for aluminum sheet on the inner warm-side surface at the stop and at the joint between the hot and cold sides to reduce heat conduction to the cold side.

The apparatus was designed for warm-side air temperatures up to 150° F, with relative humidities up to about 90 percent. The cold side was designed to attain temperatures as low as 100 degrees below the room temperature, or about -30° F, and relative humidities from about 20 to 70 percent. By means of automatic controls, temperatures and humidities on the two sides of the panel can be maintained for long periods of time at almost any desired conditions simulating those encountered in field use.

In service the orientation of a panel—depending on its use as a wall, floor or ceiling of a refrigerated chamber—may markedly affect its performance, especially with regard to moisture accumulation effects. To permit studies in different orientations, the entire apparatus is mounted on horizontal trunnions so that it can be rotated 90 degrees in either direction (in a vertical plane), thus orienting a panel in either a wall, roof or floor position.

When under investigation, a test panel is exposed to desired temperatures and vapor pressures on both sides over long periods, during which heat flow through the panel and vapor flow into and through the panel can be periodically observed. Measurements of the



Left: General view of NBS apparatus for measuring heat and water vapor permeance of insulated panels: (clockwise) the instrument console, the panel test apparatus (in vertical position), the desiccant box, and the oven for regenerating the desiccant. **Right:** Apparatus uncoupled to show the construction and associated equipment of its two well-insulated sections. The 4×8-foot test panel is installed between the warm side, left, and the cold side of the apparatus, right.

heat flow, or of its changes, provide an indication of the effect of moisture accumulation on over-all insulating value, and they indicate indirectly whether moisture is accumulating in the panel. Direct measurements of vapor flow into and out of the panel are also made.

The air temperature on the warm side is maintained constant by small electrical resistance heaters in a cylindrical tube through which air is circulated by a fan. Selected heaters are energized continuously, and one or two are energized intermittently under the control of an electronic time-proportioning thermostat whose sensing element is located in the air on the warm side of the panel. On the cold side, the air is cooled to a temperature slightly below the desired value by means of a flooded direct-expansion cooling coil through which air is circulated. An electrical strip heater controlled by a second channel of the time-proportioning thermostat (with its sensing element in the air on the cold side) is used to raise the temperature by the slight amount necessary to obtain the desired value.

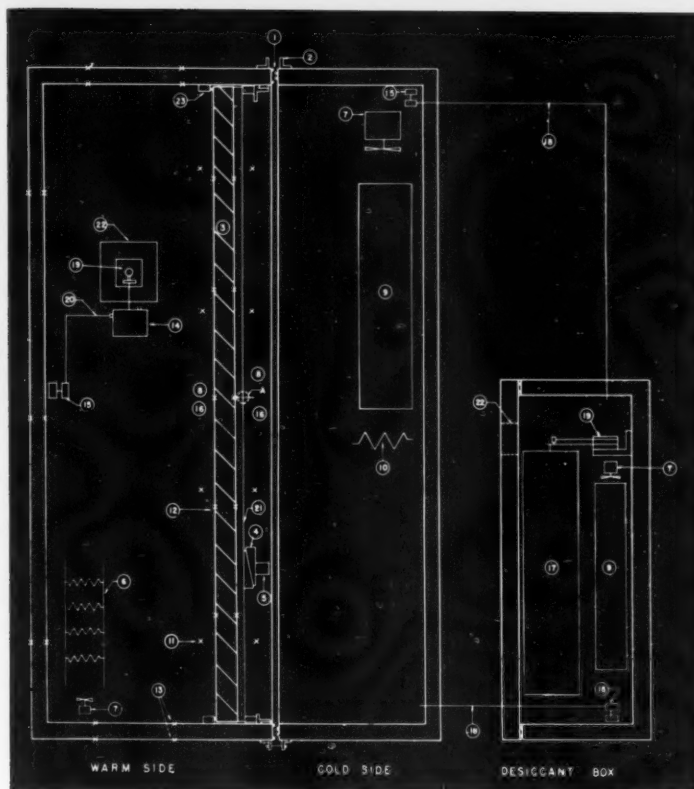
Eight thermocouples connected electrically in parallel, are used on each side of the test panel to measure the average air temperature at a distance 3 in. from the panel. Ten individual thermocouples are used to measure temperatures on each face of the panel. Leads for several additional thermocouples, and for several Dunmore-type humidity-indicating elements, are brought into the box for making measurements of conditions within the test panel during testing.

Determination of heat flow through the panel is made by measurement of the average electrical energy input into the warm side and of heat losses from the same side through all paths except that through the test panel. The difference is that going through the panel. Electrical energy input is measured by an in-

tegrating watt-hour meter. The heat losses are determined by measuring certain temperature differences and using appropriate calibration procedures.

These heat losses are the result of (1) direct transmission through the five other faces of the warm-side box to the laboratory air, and (2) conduction around the test panel to the cold side through the inner lining of the warm section. To measure the heat loss of item (1) sixteen differential thermocouples are connected in series with one junction of each located at the interface of the plywood and aluminum sheets on the outside of the warm-side section and the other at the same interface on the inside. Heat transmission through the five sides is proportional to the average emf developed by this compound thermocouple. The heat conducted around the test panel is approximately proportional to the air temperature difference of the warm and cold sides. Thus, since the average rate of heat input into the warm side during a period of the test can be evaluated from the watt-hour readings and since the two heat losses can be determined from the measured thermocouple readings during the period and constants found from calibration tests, the average rate of heat transmission through the panel, both sensible and latent, can be calculated with reasonable accuracy and with sufficient precision to indicate significant changes in the insulating value of the panel due to moisture accumulation.

The rates of flow of water vapor into the warm face of the panel, and out of its cold face, were determined periodically during a test. These measurements are based on the average rates at which it is necessary to evaporate water on the warm side, and to absorb vapor on the cold side, so that their humidities are kept at the desired constant levels.



Schematic drawing of the test apparatus shows: A, trunnion axis; 23, panel stop; 22, window; 21, panel shim; 20, hose to vapor source; 19, cantilever scale; 18, flexible hose; 17, desiccant trays; 16, humidity sensing elements; 15, centrifugal blower; 14, vapor source; 13, differential thermocouples; 12, surface thermocouples; 11, air thermocouples; 10, electric heater; 9, refrigeration coil; 8, temperature sensing elements; 7, fan; 6, heater duct; 5, wedge retainer; 4, wedges; 3, test panel; 2, angle iron; 1, gas-kets and permagum sealers.

Specific means for accomplishing this are: In the warm side a covered and insulated aluminum vessel containing water is held approximately at a desired temperature by a small electrical resistance heater cemented to the vessel bottom. When an electronic humidity controller with a Dunmore-type sensing element in the warm-side air calls for an increase in humidity, air is forced into and through the vessel, thereby conveying an increment of water vapor in the warm-side enclosure. The water container is suspended from a cantilever scale, the deflection of which is indicated by a dial gage graduated in 0.0001-in. steps. To allow freedom of angular orientation of the apparatus, the cantilever scale is mounted on its own trunnion. The dial gage is viewed through a multipane window in the wall of the warm-side section.

The water vapor transmitted through the cold-side face of the panel is adsorbed by a desiccant (silica gel) spread out in 11 wire mesh trays in a "desiccant box" connected to and external to the main apparatus. By means of flexible metallic hoses and two small blowers, air is drawn from the cold-side enclosure, passed over the desiccant, and returned to the cold side at a rate of about 4 cubic feet per minute. Control of the rate of adsorption is effected by intermittent operation of

the blowers which, in turn, are controlled by a Dunmore-type humidity sensing element in the cold section. The desiccant trays are suspended from a cantilever scale similar to that in the warm section, to enable periodic measurement of the weight of vapor adsorbed.

In operation, it is necessary to avoid condensation of vapor on the refrigerating coil in the cold side of the enclosure or on that in the desiccant box, if all the vapor transmitted through the panel is to be adsorbed by the desiccant. For this reason, the coils must be operated at temperatures above the dewpoint of the air surrounding them. They are therefore large, and are operated with large air circulation rates; furthermore, the coils are operated flooded with refrigerant to obtain maximum capacity with a small air-to-coil temperature difference.

Initial tests of the apparatus to determine calibration constants as well as two full-scale panel tests—one running continuously for 52 days—have indicated very satisfactory operational performance and results. In the last test, conducted with a test panel of homogeneous material, excellent agreement was obtained for the thermal conductivity of the panel material and its vapor permeability, as compared with determinations of these properties by other methods.

Nickel Cast Irons in Soils

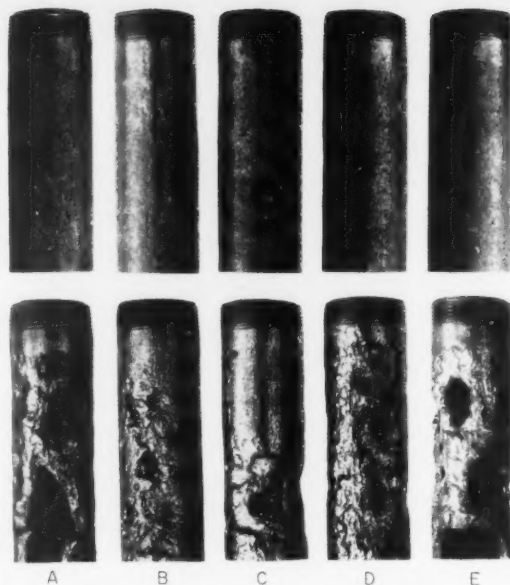
THE BUREAU has recently completed a long-range study of the corrosion of nickel cast irons in soils. From measurements on pipe specimens after exposure to different soil conditions for periods up to 11 years, it has been possible to evaluate the effect of varying amounts of nickel in the castings.

Corrosion of cast iron in soils is characterized by the development of an adherent layer of corrosion products that increases in thickness as corrosion progresses. The thickening of this layer is due, in part, to electrochemical action between the ferritic and graphitic constituents of cast iron and partly to differences in potential that arise from contact of the metal with the soil. In cast iron exposed to the air, addition of nickel or of nickel plus chromium to the casting has been found to give improved corrosion resistance by reducing galvanic action within the metal itself.¹ To determine the effect of such additions on the corrosion of cast iron in soils, the Bureau included samples of nickel cast irons in an extensive series of exposure tests of materials for underground construction. With the completion of this work, data became available for exposure up to a maximum of 11 years for specimens of low-alloy cast iron, and up to a maximum of 14 years for specimens of high-alloy cast iron. In all, 16 exposure sites were employed, representing a wide variety of soils throughout the United States. After removal of the samples from the exposure sites, weight loss and depth of pitting were measured, and the resulting data were analyzed by I. A. Denison and M. Romanoff of the Bureau's corrosion laboratory.

The study included samples of plain cast iron, low-alloy cast-iron pipe (1.27 Ni, 0.32 Cu; 1.17 Ni, 0.98 Cu; 3.32 Ni), low-alloy cast-iron plate (2.08 Ni, 1.10 Cu; 3.10 Ni), and specimens of high-alloy cast-iron pipe (15.0 Ni, 6.6 Cu, 2.6 Cr). The specimens consisted of lengths of pipe 10 to 14 in. long and 1.5 to 2.5 in. in diameter. Moisture was excluded from the interior by means of cast-iron screw caps of the same composition as the pipe. As an extra precaution against internal corrosion, the inner surfaces of the specimens were coated with heavy grease.

Weight losses and depth of pitting were correlated with the composition of the specimens and the type of soil environment to which they were exposed. From the standpoint of both criteria, the high-alloy cast iron

¹ W. A. Wesley, H. R. Copson, and F. L. LaQue, *Metals and Alloys* 7, 25 (1936).



Cast-iron pipe specimens after approximately 11 years' exposure to highly corrosive soils in long-range NBS studies. The advanced state of corrosion of these specimens is not immediately evident (top row) until corrosion products have been removed (bottom row). Directly below each specimen in the top row is the same specimen with corrosion products removed. Specimen A was exposed to Lake Charles clay at El Vista, Tex.; B to muck at New Orleans, La.; C to tidal marsh at Charleston, S. C.; D to Docas clay at Cholame, Calif.; and E to Merced silt loam at Buttonwillow, Calif.

was considerably more resistant to corrosion than either the plain cast iron or the low-alloy cast irons. Except in cinders, the deepest pit measured on the high-alloy specimens was only 74 mils after 14 years of exposure.

In the low-alloy cast irons, additions of nickel up to 3 percent were found to reduce initial corrosion in poorly drained soils of low resistivity, but this advantage was not maintained for the duration of the tests. Thus, the weight losses of the low alloy cast irons exposed for the maximum period did not differ greatly from the losses of the plain cast iron. Hence, it would appear that the rates of corrosion of the alloys containing as high as 3 percent nickel decrease less with time than do the rates for plain cast iron and the alloys containing smaller amounts of nickel.

Measurements of hydraulic bursting pressure were also made on samples of the nickel cast irons after exposure to the different soil conditions. Because the original shape and appearance of the metal are retained, visual observation gives no indication of the extent of corrosion in cast iron that has been buried. It is generally recognized that corroded cast iron retains some of its original strength, but the extent to which cast-iron pipe may corrode underground and still re-

TABLE 1.—Hydraulic bursting pressures and number of perforations of pipe samples

Soil	Exposure	Sample	Plain casting iron		1.27% Ni, 0.32% Cu		0.98% Cu, 1.17% Ni		3.32% Ni	
			Bursting pressure	Number of holes	Bursting pressure	Number of holes	Bursting pressure	Number of holes	Bursting pressure	Number of holes
	<i>Years</i>		<i>lb/in.²</i>		<i>lb/in.²</i>		<i>lb/in.²</i>		<i>lb/in.²</i>	
Lake Charles clay (El Vista, Tex.)	7.2	a	350	2	500+	1	500+	1	500+	1
		b	500+	1	500+	1	500+	1	500+	1
	8.7	a	500+	3	500+	1	500+	3	500+	2
		b	500+	1	500+	1	500+	1	500+	1
	10.9	a	500+	1	500+	1	500+	1	500+	1
		b	500+	5	500+	10	500+	6	500+	8
Muck (New Orleans, La.)	7.2	a	500+	1	500+	1	500+	1	500+	1
	10.9	a	500+	1	500+	1	500+	2	500+	1
Docas clay (Cholame, Calif.)	7.2	a	500+	6	0	7	150	10	500+	3
		b	500+	5	200	5	150	6	500+	1
	8.8	a	425	4	500+	4	375	4	500+	2
		b	500+	2	500+	3	375	4	500+	2
	11.0	a	500+	10	225	6	225	6	500+	3
		c	500+	1	225	6	225	6	350	7
Mohave fine gravelly loam (Phoenix, Ariz.)	7.2	a	450	5	500+	14	500+	6	500+	7
		b	500+	4	500+	11	0	12	0	14
	8.8	a	500+	1	500+	6	500+	7	500+	9
		b	500+	1	500+	6	500+	7	500+	9
Merced silt loam (Buttonwillow, Calif.)	7.2	a	500+	5	0	14	500+	6	500+	7
		b	500+	4	0	11	0	12	0	14
	8.8	a	500+	1	500+	6	500+	7	500+	9
		b	500+	1	500+	6	500+	7	500+	9
	11.0	a	500+	12	175	18	500+	7	500+	9
		c	500+	11	500+	6	500+	7	500+	9

tain sufficient strength to withstand the pressures commonly used in water- and gas-distribution systems had not previously been estimated.

In order to evaluate the residual strength of corroded cast-iron pipe, the samples of pipe that had been removed from the more corrosive soils after the longer periods of exposure were subjected to hydraulic pressures. The screwcap on one end of each sample was replaced by a similar cap in which a fitting had been inserted, and the pipe section was connected by copper tubing to a hand pump of suitable capacity. The pressure was increased at the rate of approximately 10 lb./in.²/sec until failure of the pipe occurred or the maximum pressure of 500 lb./in.² was attained. After the application of hydraulic pressure, the corrosion products were removed and the condition of the specimens was evaluated in the usual manner.

After exposure at the test sites for periods up to 11 years and storage in the laboratory for approximately

1 year, most of the specimens withstood a maximum pressure of 500 lb./in.², even though the subsequent removal of the corrosion products revealed numerous holes of various diameters (table 1). Most of the low bursting strength values that were obtained probably were not accurate measures of the strength of the corroded pipe at the time of its removal from the soil since these low values may have resulted from oxidation of the corrosion products during storage or damage to the pipe in handling and shipment. Hence, it is reasonable to assume that undisturbed buried cast-iron pipe, even in an advanced state of graphitic corrosion, is able to withstand the minimum pressure required of class 150 pipe. The partial results of incomplete field tests of the bursting pressure of undisturbed sections of plain cast-iron pipe are in good agreement with the measurements made on the stored samples.

For further technical details, see Corrosion of nickel cast irons in soils, by Irving A. Denison and Melvin Romanoff, *J. Research NBS* 51, 313 (1953).

Computation of Achromatic Objectives

Computation of Achromatic Objectives, by Robert E. Stephens, National Bureau of Standards Circular 549, presents algebraic procedures by which amateur telescope makers can design their own lenses. The computation of curves for achromatic doublet objectives is outlined in detail with illustrative examples. Criteria for choosing particular pairs of glass types and means of achieving various degrees of correction are also discussed.

Although there is considerable interest among amateurs in the design of telescope objectives, very few

designs are published where they are accessible to the layman. Moreover the characteristics of the published designs are seldom adequately described, and they often require optical glasses that are no longer available. NBS Circular 549 not only provides the reader with a guide for computing achromatic objectives to his own specifications but also serves as an introduction to the algebraic method of lens computation for those who may wish to delve further into the design of lens systems. This Circular is available for 10 cents from the Superintendent of Documents, U. S. Government Printing Office, Washington 25, D. C.

High-Stability

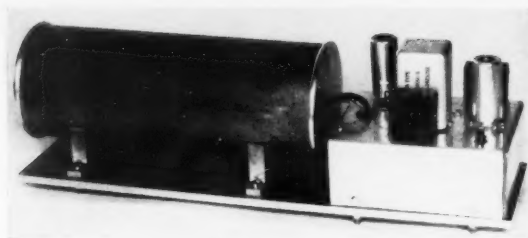
One-Megacycle

Frequency Standard

A PORTABLE one-megacycle frequency standard, stable to a few parts in 100 million per day, has been developed by P. G. Sulzer of NBS. The compact and relatively simple assembly, employing inexpensive commercially available components, makes use of a crystal unit to control the frequency of an oscillator. The device is sufficiently rugged for general laboratory and field use as a working standard. It is expected to have wide application in checking radio transmitters and measurements, and in various other industrial and research fields.

As custodian of the national standards of physical measurement, the Bureau develops and maintains basic standards for electrical quantities at all radiofrequencies. From these basic standards are obtained the secondary standards used by research laboratories and the radio industry. As science and technology advance, research must constantly be conducted to meet increasing demands for more precise and reliable secondary standards of frequency, the Bureau has made a continuous effort to improve the performance of crystal-controlled oscillators, which appear to offer the best solution in the present state of the art.

The NBS one-megacycle standard, like other crystal-controlled oscillators of this type, consists of three elements: the crystal unit proper, an amplifier or negative-resistance device to supply the losses in the



The NBS one-megacycle frequency standard showing the crystal oven (left) and the accompanying electronic equipment (right).

crystal unit and to deliver power to a load, and an amplitude control. However, the NBS oscillator was specially designed to minimize frequency changes caused by tube or component instability. As a result, the over-all stability of the unit is nearly that of the crystal itself.

Any phase shift in the amplifier must be offset by a corresponding but opposite phase shift in the crystal unit, which will produce a frequency change. Such a phase shift can be caused by an actual reactance change or by a variation in the reactive component of the input impedance of the tube. Phase shifts can also be produced by the electronic component of the input capacitance of a tube, by transit time, and by the effects of nonlinearity.

In the NBS oscillator, the effects of these amplifier variations are decreased by the use of inverse feedback. The familiar Meacham bridge oscillator is utilized because it gives excellent results with comparatively simple circuitry.

The Meacham bridge consists basically of a crystal resistance R_1 , a pair of resistors R_2 and R_4 , and a lamp resistance R_3 . These components are so arranged that negative feedback occurs through R_1 and R_2 while positive feedback occurs through the lamp R_3 and resistor R_4 . If the amplifier has sufficient gain, oscillation will start at the frequency of minimum degeneration, which is nearly the series-resonant frequency of the crystal, and the lamp resistance will increase with the amplitude of oscillation until the bridge is nearly balanced. When an equilibrium is reached, the bridge attenuation must equal the amplifier gain.

Good phase stability of the amplifier requires a large voltage gain (A) and a maximum transmission (B) through the negative-feedback path. However, certain practical considerations limit the increase of transmission. With a given amplifier, the product of A and B cannot be increased without increasing the crystal current or decreasing the lamp voltage, both of which are undesirable. The 20-ohm glass-enclosed, contoured AT-cut crystal chosen for the present oscillator has a Q of 5×10^5 and a maximum current limitation of 1 milliampere. The A-1 switchboard lamp R_3 used in the bridge requires at least 0.7 volt for proper operation, so that with a crystal current of 0.7 ma, R_2 is approximately 1,000 ohms, and the transmission is

Schematic circuit diagram of the NBS one-megacycle frequency standard. The Meacham bridge circuit is at lower left.

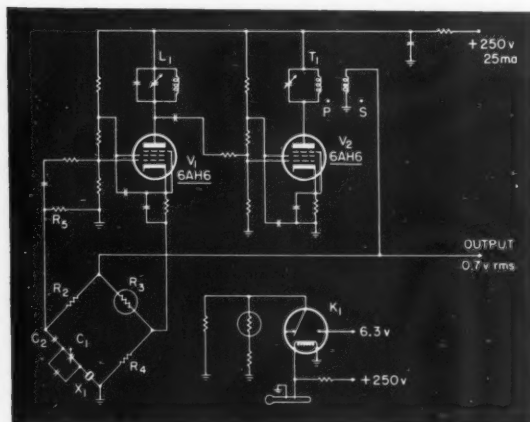
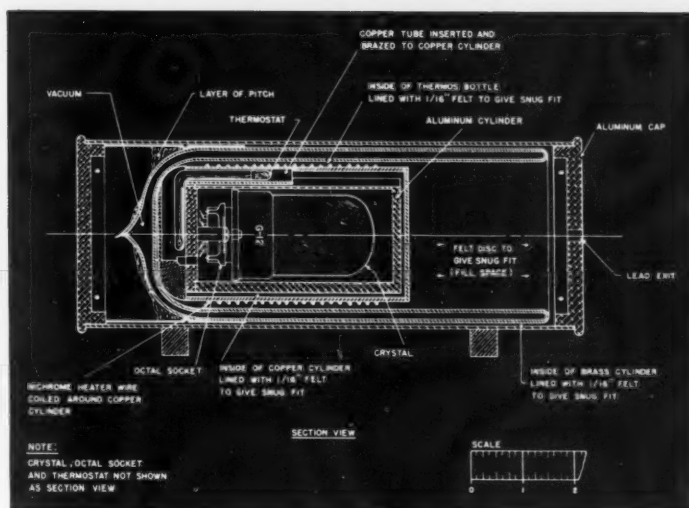


Diagram of the oven used to maintain the crystal of the NBS one-megacycle standard at a specific constant temperature.



approximately one-fiftieth. If the gain equals 1,000, then the product A times B is approximately 20, and a 20-fold reduction in effective phase shift is obtained.

Sufficient voltage gain for good amplitude stability requires two amplifier stages. The crystal current must be kept constant because the resonant frequency is a function of current. With two similar stages the voltage gain is squared, while the shift is at most doubled, permitting sufficient gain without greatly increased phase shift.

A two-stage amplifier with a voltage gain of 1,000 exhibits a maximum phase shift of ± 10 degrees over a two-to-one supply-voltage range. Thus, when the Meacham bridge is used, the maximum expected phase change with feedback becomes ± 0.5 degrees. The crystal must experience the same phase shift, and its frequency will be pulled accordingly. A simple calculation shows that with Q approximately 5×10^5 , the

corresponding fractional frequency change is $\pm 1 \times 10^{-5}$. Thus, with reasonably constant supply voltages, the short-term frequency stability can be expected to be somewhat better than this. The long-term stability will depend on these and other factors, however, including the drift of the crystal resonator itself.

To obtain the best frequency stability, the AT-cut crystal used is kept in an oven at a specified, constant temperature. The oven is of a single-stage type, with temperature control provided by a 50-degree mercury thermostat. A Dewar flask is used to isolate the controlled oven chamber from outside temperature changes. Consequently, the average power requirement is only 0.4 watt at a temperature difference of 25 deg C. Frequency changes in the crystal due to oven cycling are less than 10^{-9} cps, and normal laboratory temperature changes are apparently not reflected in the temperature of the crystal.

Miniaturization

Miniature Intermediate-Frequency Amplifiers, by Robert K-F Scal, National Bureau of Standards Circular 548, makes available to the electronics industry results of some of the Bureau's work in the miniaturization of radar components.

Size and weight reduction of electronic equipment is becoming increasingly important for many applications, particularly in military equipment. A continuing program for the development of miniaturization techniques and their application to airborne electronic equipment has been carried out at the National Bureau of Standards under the sponsorship of the Bureau of Aeronautics and the Bureau of Ordnance, Department of the Navy. One phase of this program, the miniaturization of radar components, has resulted in a number of innovations in electronic miniaturization technology. The purpose of this Circular is to make

the results of some of this work more readily available to the electronics industry.

Three miniature high-gain, high-frequency, intermediate-frequency amplifiers (20 to 100 Mc) were developed with particular emphasis on the use of circuit elements suitable for maximum design simplicity, circuit flexibility, and ease of manufacture. The units are about one-eighth the size and one-half the weight of the equipments they supersede. Circuitry was designed with emphasis on use of subminiature tubes and their application in low-noise input circuits. Some units are hermetically sealed for protection against contamination and moisture, and to provide for operation under extreme range (-65° to 200° C) required for such equipment. The Circular is available, for 40 cents, from Superintendent of Documents, U. S. Government Printing Office, Washington 25, D. C.

President Eisenhower Dedicates NBS Boulder Laboratories



PRESIDENT DWIGHT D. EISENHOWER formally dedicated the Boulder (Colorado) Laboratories of the National Bureau of Standards on September 14. The dedication climaxed a week-long program of scientific conferences and lectures, an open house, and other activities held in connection with the opening of the new laboratories. Also participating in the program were Secretary of Commerce Sinclair Weeks; Dr. Allen V. Astin, Director of the National Bureau of Standards; and Dr. Frederick W. Brown, Director of the NBS Boulder Laboratories.

The ceremony marked the completion and occupancy of the radio laboratory building by the Central Radio Propagation Laboratory, one of the two major NBS activities making up the Boulder Laboratories. The second activity is the Cryogenic Engineering Laboratory, which has been located at Boulder for something over two years.

Other events of the program included scientific conferences in both fields of research carried out by the Boulder Laboratories. The Cryogenic Engineering Conference was the first national conference devoted entirely to the *engineering* phases of low-temperature research. Summary reports of these conferences are given on the following pages.

The Buildings and Site

The new radio laboratory building is a reinforced concrete, wing-type structure featuring a four-story central spine, with one-story wings extending on either side at the second and third floor levels. Another pair of wings can also be added at the fourth floor level. The design takes advantage of a sloping terrain that rises toward the Flatiron Mountains at the west, making all floors accessible from ground level. The building has a gross area of 227,000 square feet and a net floor space of 172,000 square feet.

A number of special features have been included, such as rooms with exact temperature and humidity

At a banquet for those attending both conferences, held at the University of Colorado on September 9, greetings were brought to the Boulder Laboratories by academic leaders of the area: Dr. Ward Darley, President of the University of Colorado; Dr. W. E. Morgan, President of Colorado Agricultural and Mechanical College; Dr. John W. Vanderwilt, President of the Colorado School of Mines; Dr. Chester M. Alter, Chancellor of the University of Denver; The Reverend Richard F. Ryan, President of Regis College; and Lieutenant General H. R. Harmon, Superintendent of the U. S. Air Force Academy.

Field trips were conducted to the High Altitude Observatory at Climax for the dedication of the Observatory's new solar laboratory and coronagraph on September 9, to the Inter-University High Altitude Laboratories at Mt. Evans and Echo Lake under sponsorship of the University of Denver, and to the NBS Cheyenne Mountain Field Station at Colorado Springs.

The Denver section of the Institute of Radio Engineers sponsored a lecture, "The Sun and Radio Communications", on Friday evening by Dr. Donald H. Menzel, Director of the Harvard College Observatory.

controls to permit precision experiments, radio-shielded rooms to minimize electrical interference, stable platforms for mounting delicate instruments, an open-roof laboratory for unconfined radio experiments, and access doors for bringing mobile radio test vehicles directly into the building. A window canopy of novel design minimizes the amount of direct sunlight received in the laboratory rooms. The building also has an arrangement by which administrative areas such as the library, auditorium, and main offices can be readily isolated from the laboratory area in case it becomes necessary to impose security restrictions.

The NBS-AEC Cryogenic Engineering Laboratory consists of three principal units: a liquid hydrogen plant, a liquid nitrogen plant, and laboratories for research and development. Two large concrete buildings—one housing the liquefying plants and the other for the experimental laboratories and shop—provide a total floor space of 34,000 square feet. There are also several auxiliary buildings and test sites.

Both major buildings are equipped with safety and antiexplosion devices to minimize the hazards of working with liquid hydrogen in large quantities. The

hydrogen liquefying and purifying equipment, which was designed and constructed by NBS, is in duplicate so that the plant can be operated continuously without shutdown. The experimental laboratories have been designed with emphasis on versatility in order to make possible continuing research in a variety of fields of science and engineering as the need arises.

The Boulder Laboratories are located on a 217-acre site purchased and donated to the Government by 296 citizens and business groups of the area. A commemorative plaque was unveiled on September 13.

*Remarks of President Dwight D. Eisenhower
at the Dedication of the
Boulder Laboratories, National Bureau of Standards
September 14, 1954*

Mr. Secretary, Dr. Astin, My Friends: For the past 30 minutes or so, I have had the great privilege of a personally conducted tour through certain of the facilities of these new laboratories.

Now, the things that the layman sees in these laboratories are not to be understood by him. He grasps, though, that something of the most tremendous significance is proceeding here—significant not only to the scientist, to industry, or to the facility that may use the products of that science and the discoveries which the scientist makes, but significant also to our Nation and to each of us, to our children, to the progress toward security and prosperity that each of us so desperately longs for.

It seemed to me, as I went through with Dr. Astin, that here we have a new type of frontier. This spot only a few short decades ago was inhabited by Indians and by buffalo, and, later, by trappers and miners. It became the center of a great mining and agricultural region, which has meant so much to the United States in the past—and indeed does now.

But the frontier days when we could go out and discover new land—new wonders of geography and of nature—have seemed largely in the past. Here today, inside this building, we have a frontier of possibly even greater romantic value, as well as greater material value to us, than were some of the discoveries of those days.

Another thought came to me as I went through these laboratories. In recent years, scientists have produced so much that terrifies us with its destructive force, that we begin to think of science as only something to destroy man, and not to promote his welfare, his happiness, his contentment—his intellectual and spiritual growth.

But I believe, if we think of it this way, we will drop such thoughts from our minds: Almost everything that man has discovered in his long, long journey from darkness toward the light has been capable of two uses: one good, one evil.

Way back, long before history was started, man discovered fire, and without fire we wouldn't be warm, we couldn't cook—we would still be in the depths of savagery.

Yet look how destructively fire can operate.

Again, take dynamite. We think of dynamite as a weapon of war, yet how much of it has been used in your hills here, in the great lead, zinc, silver, and gold mines that have made Colorado famous and rich.

I submit that every discovery of science can be used in one or two ways. It is not the fault of science, if it is used wickedly. It is within ourselves.

And therefore, in the words of him who gave our invocation, possibly each one of us is a laboratory, to discover what we can contribute toward the growth of that kind of spirit among men that will make all of the discoveries of these dedicated scientists become assets to us, as we try to develop for ourselves and our children a better life, a richer life, one that gives us more opportunity to grow intellectually and spiritually.

It is, then, in those terms that we should look on the growth of science, as we think of the men laboring in this building, of the scientists in our universities, in the National Bureau of Standards in Washington—in the great laboratories and factories of our Nation.

And I think that if each one of us does his part, then we will steadily go down the ages as a people more prosperous, more happy, more secure, more confident in peace.

Now those are the thoughts that occurred to me as I walked through these buildings. We believe this region of the United States is fortunate in having this facility here, to remind you day by day, and so that you may, at least in a sense, become a part of some of the great discoveries that will be so useful to mankind—now, and through all the years yet to come.

I have now two little duties to perform. The first, most pleasurable, is to thank you—each of you—for your welcome to me, for the cordiality of your reception.

The second is that I am privileged to push a button—of course, this dedication must be scientifically done—you couldn't do it by just pulling a cord. When I push this button, I am told that I am going to release a veil over the cornerstone.

In so doing, it is my high privilege to dedicate this facility of the National Bureau of Standards to the welfare of humanity—in America and throughout the world.

The Boulder Laboratories

Four scientific divisions have been established at the Boulder Laboratories. The Cryogenic Engineering Laboratory constitutes one division and the Central Radio Propagation Laboratory,¹ which has previously been a single division in the NBS organization at Washington, now consists of three divisions. Each represents a different phase of CRPL research: Radio Propagation Physics, Radio Propagation Engineering, and Radio Standards.

Cryogenic Engineering Laboratory

The NBS-AEC Cryogenic Engineering Laboratory, headed by Russell B. Scott, was established in cooperation with the Atomic Energy Commission. It provides facilities for development and evaluation of engineering materials and equipment for use at very low temperatures—temperatures which may be as low as -450° F or several hundred degrees below the coldest ever observed in the most severe climates. Such temperatures, which are attained with liquefied gases (oxygen, hydrogen, nitrogen, and helium), are being used more and more in national defense and industry, and for laboratory research. This has necessitated larger, more convenient, and less hazardous equipment for producing and handling these gases.

As a result, many new and highly complex engineering problems have arisen in the low-temperature field, where much remains to be learned about the behavior of engineering materials. At the temperature of liquid

hydrogen, for example, normally trustworthy steels become brittle, rubbers lose their elasticity, and the mechanical properties of most plastics are greatly altered.

The Cryogenic Engineering Laboratory consists of four sections, with responsibilities indicated by their names: Cryogenic Equipment, Cryogenic Processes, Properties of Materials, and Gas Liquefaction.

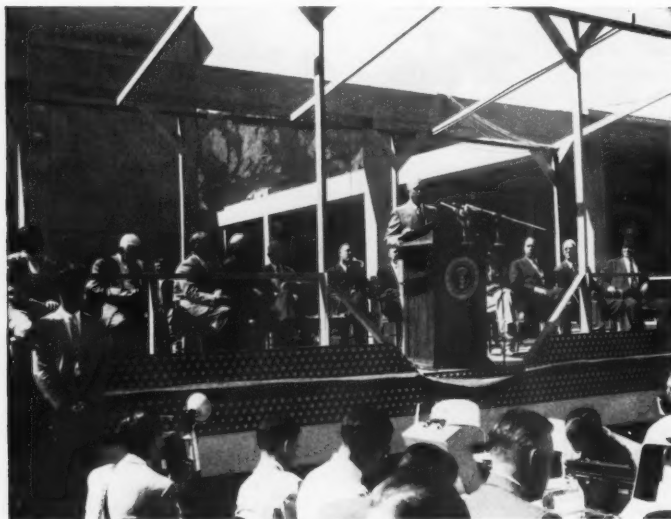
Central Radio Propagation Laboratory

Radio propagation research at NBS extends back to 1909 when measurements were made of very long radio waves, which traveled comparatively short distances and only along the surface of the earth ("ground-wave" transmission). Four years later the radio work was established as a section of the Electricity Division.

Studies were extended to include higher frequencies after the basic demonstrations of ionospheric reflection of radio waves in 1926 by Breit and Tuve of the Carnegie Institution of Washington. (See the report of an invited paper given by Dr. Tuve at the Conference on Radio Propagation and Standards, page 169.) In the subsequent decade NBS increased the scope and extent of its ionospheric measurements and theory, and developed techniques that were incorporated later into military radar and radio. The Bureau's program not only included the study of radio physics but the development of widely used navigation aids such as the aircraft radio beacon and ILS Blind Landing System.

The Radio Section remained in the Electricity Division through both World Wars and the intervening years, until the Central Radio Propagation Laboratory was formed in 1946 by joint action of a number of Federal agencies and with concurrence of the Congress. CRPL took over the functions of the Interservice Radio

¹ For more complete details of the technical programs of these laboratories, see NBS-AEC Cryogenic Engineering Laboratory, NBS Technical News Bulletin 37, No. 10, 152 (October 1953); and NBS Research in Radio Propagation, NBS Technical News Bulletin 38, No. 4, 49 (April 1954).



President Dwight D. Eisenhower speaking at the dedication of the NBS Boulder Laboratories. Seated on the speaker's platform, left to right, are Dr. Frederick W. Brown, Director of the Boulder Laboratories; State Senator Don Brotzman of Colorado; Honorable Cliff Clevenger, Congressman from Ohio; Governor Dan Thornton of Colorado; Secretary of Commerce Sinclair Weeks; Dr. Donald Menzel, Director of the Harvard College Observatory; Mayor Quigg Newton of Denver; Mayor John Gillaspie of Boulder; Dr. Allen V. Astin, Director of the National Bureau of Standards (partly hidden behind the speaker's podium); Assistant Secretary of Commerce James C. Worthy; Honorable William S. Hill, Congressman from Colorado (Fort Collins); and Honorable Byron G. Rogers, Congressman from Colorado (Denver).

*Statement of Dr. Allen V. Astin, Director
National Bureau of Standards
at the Dedication of the Boulder Laboratories*

Early in World War II there were tragic instances of aircraft failing to return to their home base because of loss of radio contact. Ironically, if the right radio frequency to use had been known this contact probably need not have been lost. This and related situations led the military services to establish at the National Bureau of Standards in 1942 an Interservice Radio Propagation Laboratory to provide essential data concerning radio propagation conditions. In 1946, through the joint action of several Federal agencies the Central Radio Propagation Laboratory was established to take over the function of the Interservice Laboratory as a long-term peacetime project.

Its functions include the collection, analysis and dissemination of information on natural phenomena which affect radio communication, as well as fundamental research on the mechanism of the transmission of radio waves in order to make more efficient use of the radio frequency spectrum. In addition, the Laboratory develops standards for measurements in radio frequency and provides essential calibration services to the radio and electronics industry.

To assure that the program of the Central Radio Propagation Laboratory meets in an effective manner the service needs of various Government agencies and industrial groups, close coordination is necessary. This is provided by an advisory committee consisting of representatives of the Army, Navy, Air Force, Federal Communications Commission, Civil Aeronautics Administration, Coast Guard, and the State Department, together with representatives from interested industrial and professional groups.

The Congress provided authorization for a laboratory building for CRPL in 1950 with the suggestion that it would

be desirable to locate the facilities outside of the Washington area. A Site Selection Board finally recommended Boulder as the location best meeting all of the important criteria. Shortly thereafter, the citizens of Boulder through private contribution generously offered to the Government the tract of 217 acres on which the laboratory buildings are located.

About two years ago, there was placed in operation on this site the AEC-NBS Cryogenic Engineering Laboratory for the study of physical and engineering problems, and the properties of materials, at very low temperature.

The new laboratory building which houses the Central Radio Propagation Laboratory is a reinforced concrete wing-type structure, having a gross area of 227,000 square feet and a net floor space of 172,000 square feet. The design of the building includes a number of special features, such as stable platforms for mounting delicate instruments, an open-air roof laboratory for unconfined radio experiments, and ground level access to all floors, except the roof.

The building was designed by architects Pereira and Luckman, J. E. Stanton, and Robert Ditzen, the latter a local Boulder architect.

The building was erected by the Olson Construction Company at a contract price of \$3,335,000. Architects' fees, special equipment, and activation expenses brought the total cost to about \$4,000,000.

The design and construction of the building was supervised by the Public Buildings Service of the General Services Administration.

With this fine new facility now available, the Bureau will strive to fulfill its scientific and technological responsibilities in such a manner as to warrant fully this public trust.

Propagation Laboratory, which had been created at NBS by the military agencies during World War II to supply vital data needed at that time for maintaining reliable radio communication between distant points.

Radio Propagation Physics Division

The Radio Propagation Physics Division, headed by Dr. Ralph J. Slutz, deals with the physics of radio wave propagation with particular reference to the ionosphere, a series of electrically conducting layers of the earth's atmosphere extending as much as several hundred miles from the earth's surface. This work includes studies and experiments to find out how the ionosphere is formed and how it affects radio communication. One aspect is a study of the relationships between the sun and earth, for the sun is the primary source of the radiations which create the ionosphere.

A very practical result of this work is the publication of basic radio propagation predictions, three months in advance. These are world-wide charts from which can be computed the best frequencies for use

over any transmission path for any time during the prediction period.

Three sections make up the division: Upper Atmosphere Research, Ionospheric Research, and Regular Propagation Services.

Radio Propagation Engineering Division

The primary responsibilities of the Radio Propagation Engineering Division, of which Kenneth A. Norton is chief, are tropospheric or "line-of-sight" propagation research and related studies of frequency utilization. Tropospheric propagation research is necessary to measure and evaluate the effects which terrain, climate, and meteorology have on very-high-frequency (VHF), ultra-high-frequency (UHF), and microwave radio systems. The increasing use of the radio spectrum in these frequency ranges by the defense agencies, commercial airlines, and the broadcasting industry (television and FM) makes it essential to have propagation information in order to understand the transmission characteristics and to make the best use of the

frequencies available. Frequency utilization studies are designed to provide technical data that will assist in the allocating, regulating, and advisory activities of such agencies as the Federal Communications Commission and the Department of Defense.

The division consists of two sections, Frequency Utilization Research and Tropospheric Research.

Radio Standards Division

The National Bureau of Standards, through the Radio Standards Division headed by Dr. Harold A. Thomas, conducts a continuing program for the establishment, maintenance, and improvement of basic standards and precision methods of measurement throughout the radio frequency spectrum. There are two branches, High Frequency Standards and Microwave Standards.

NBS maintains the national primary standard of frequency, which is electronically multiplied and divided to produce a whole series of standard frequency signals ranging from a few cycles up to 100,000 megacycles. From these are derived a series of carrier frequencies, as well as precise time intervals and standard audio frequencies, which are broadcast from the Bureau's radio stations, WWV (located near Wash-

ington, D. C.) and WWVH (Maui, Hawaii). One of these audio frequencies (600 cycles) is very important to the electric power industry which uses it to control the generation of 60-cycle current. Another standard audio frequency, 440 cycles, is the standard musical pitch, A above middle C. These stations also broadcast a number of other standard services, including correct standard time and warning of ionospheric disturbances.

Other basic standards and precision methods of measurement developed and maintained by NBS in the high frequency and microwave regions include the electrical quantities such as power, voltage, current, impedance, attenuation, field strength, noise, dielectric constant, and magnetic permeability. As an illustration, the standard of radio signal field strength is important in connection with proving the performance of radio stations (AM, FM, and TV) and maintaining them on their assigned frequencies. Interference in the radio spectrum is evaluated by means of field strength meters calibrated at NBS.

The cesium beam "atomic" clock developed by scientists in this division has been used to make the most accurate measurements ever recorded by man. Thus the potential accuracy of new time and frequency standards is 1 part in 10 billion or 1 second in 300 years.

The Scientific Conferences

1954 Cryogenic Engineering Conference

A three day program of technical papers was presented at the 1954 Cryogenic Engineering Conference, under chairman M. M. Reynolds of the NBS Cryogenic Engineering Laboratory. This was one of two scientific meetings accompanying the dedication ceremonies of the NBS Boulder Laboratories on September 8-14. A registration at the Cryogenic Engineering Conference of over 200 scientists and engineers from all parts of the country was evidence of the considerable current interest in this field, one which has not as yet found a satisfactory place within the bounds of existing professional societies.

R. B. Scott, Chief of the NBS-AEC Cryogenic Engineering Laboratory, called the Conference to order on

Wednesday morning, September 8, and introduced Dr. F. W. Brown, Director of the NBS Boulder Laboratories, who briefly welcomed the delegates. Dr. F. G. Brickwedde (Chief, Heat and Power Division, NBS, Washington), the first invited speaker, chose a particularly appropriate subject for the opening address of this conference, "Some Remarks on the Beginnings of the Cryogenic Engineering Laboratory, Boulder". Dr. Brickwedde related the early history of the Laboratory and discussed some of the features of the large NBS hydrogen liquefiers.

The remainder of the first day was devoted to contributed papers on cryogenic equipment, including large liquid oxygen and liquid nitrogen vessels (Herrick L. Johnston, Inc., Ronan and Kunzl). The utilization of liquid oxygen as a source of breathing oxygen in aircraft was another extremely interesting development reported (Wright Air Development Center). Large transportable types of liquid hydrogen vessels, some of which are capable of being refrigerated, were described (Herrick L. Johnston, Inc., Cambridge Corporation, and NBS). Hydrogen loss rates as low as 0.6 percent of rated capacity per day have been achieved, giving some idea of the present efficiency of this type of liquefied gas storage. Refrigeration cycles employed with the aforementioned Dewars, utilizing both condensation and reliquefaction principles, were also discussed (Arthur D. Little, Inc., and NBS).

The "B" building of the Cryogenic Engineering Laboratory which houses offices, shops, and laboratory facilities.



President Eisenhower pushes a button to unveil the cornerstone of the Boulder Laboratories.

Aluminum was reported to be a useful construction material for both liquid oxygen and liquid hydrogen vessels and a paper on the joining of aluminum to stainless steel (NBS) was particularly interesting since aluminum to stainless steel tube joints are a prerequisite to the success of the all-aluminum liquid hydrogen vessels.

Some aspects of the transfer of liquefied gases through piping systems were discussed (NBS), placing into proper perspective the importance of the various factors such as heat leak and container pressure, in transfer operations. Performance of a large air expansion engine used in conjunction with an NBS nitrogen liquefier was examined.

A tour of the NBS Cryogenic Engineering Laboratory was arranged for the delegates at the close of the first day's sessions.

The evening of the first day was devoted to a forum on low-temperature instrumentation. Successful application of commercial radio-type carbon resistors to low-temperature thermometry was reported. A cryostat capable of maintaining any desired temperature in the range between room temperature and -320°F (liquid nitrogen) within one degree F was described. A simple immersion type of optical device for detecting liquid level was demonstrated and attracted considerable interest. A group of short papers by various NBS workers was devoted to determination of ortho-para composition in hydrogen, liquid-level devices (using capacitor transducers, linear-differential-transformer-type transducers, and commercial carbon resistors), an integrating and remote-indicating mass flowmeter for hydrogen gas, methods for trace oxygen analysis in hydrogen of variable ortho-para composition, application of electric circuit theory to the analysis of pulsation dampers for pressure gauges, the low temperature resistivities of some commercial conductors, and a thermistor flowmeter for gases.

The second invited paper, by P. V. Mullins (Chief, Helium Division, Region VI, U. S. Bureau of Mines) opened the session on Cryogenic Applications, on the second day of the conference. The Bureau of Mines has been active in the cryogenic engineering field for quite a long time and the conference was fortunate in having Mr. Mullins report on such an historical application of cryogenic engineering as the Bureau of Mines helium production process. Applications of cryogenic liquids and cryogenic engineering in guided missiles (Redstone Arsenal), in the production of chemicals (Blaw-Knox Co.), in the production and distribution of liquefied atmospheric gases (Linde Air Products Co.), and in low temperature testing with carbon dioxide (Liquid Carbonic Corp.) were contributions received during the remainder of the session.

A group of papers (Ohio State University, NBS, and Dow Chemical Co.) was devoted to porous thermal insulators. Experimental data were presented showing that high insulating efficiency can be obtained with powders at moderate vacua, and that addition of pow-



dered metal may further reduce the radiative component of heat flow through such insulators. Data on the absorptivities for thermal radiation of various metals were presented (NBS). Of particular interest was the finding that mechanical polishing may reduce the reflecting efficiency of a surface due to cold working of the surface layer of metal.

A group of papers (NBS, Westinghouse, and M.I.T.) was devoted to methods of measuring mechanical properties at low temperatures. Yield-strength data on some commercial structural alloys were presented. Techniques for experimentation at high pressures and low temperatures were described (General Electric Co.) and a paper (NBS) described an apparatus for measuring thermal conductivities down to 4°K and reviewed data in this field. Determinations of thermal conductivities, expansion coefficients, and compressibilities of solids and compressed gases were discussed in a paper (Cryogenic Laboratory, Ohio State University) in which it was noted that type 304 stainless steel and uranium both expand with decreasing temperature somewhat below 50°K .

A paper describing a cryostat for obtaining precisely controlled temperatures in the vicinity of the boiling point of nitrogen (Spaco, Inc.) was followed by a group of papers (Ohio State University and NBS) reporting experimental studies of the kinetics of catalytic ortho-para conversion of hydrogen in both the liquid and the gas phase. A vibration test facility of 20,000 pound capacity built at NBS from commercially available components was described and also demonstrated during tours of the laboratory. Some experiences with spontaneous acoustic oscillations in cryostat tubes located in a temperature gradient (NRL) were identified with similar phenomena mentioned as far back as Rayleigh's theory of sound.

The final day was devoted to a discussion of cryogenic processes. Dr. L. I. Dana (Vice President, Research, Linde Air Products Co.) prepared an invited paper on theory versus applications in low-temperature engineering. His paper dealt with such cryogenic processes as the Joule-Thomson expansion, distillation, heat exchangers, and insulation, and was presented by Marne A. Dubs (Linde Air Products Co.).

Both portable (Herrick L. Johnston, Inc.) and stationary (NBS) liquid hydrogen plants were described in the contributed papers. It is interesting to note that these plants are among the largest ever constructed and are a credit to the engineers and scientists working on cryogenic problems in this temperature range.

In addition, processes at higher temperature levels dealing with a freon cascade refrigerator as a liquid air plant precooler (Los Alamos Scientific Laboratory); manufacture, liquefaction and distribution of Dry Ice and carbon dioxide (Liquid Carbonic Corp.); and the effect of some variables in low-temperature gas separation processes for liquid air (Air Products Co.) were described.

At the close of the conference, Mr. Scott reported the results of a questionnaire which the conference delegates had completed. In brief, a very large number favored continuing the national cryogenic engineering conferences on an annual basis. It was felt that this conference properly covered cryogenic engineering subjects; however, a large number reported that they would like to see the temperature range limited to 150° K and below.

Conference on Radio Propagation and Standards

The Conference on Radio Propagation and Standards, one of the two scientific meetings held in connection with the dedication of the Boulder Laboratories, included eight invited papers, five of which were given at the Friday morning session presided over by Dr. F. W. Brown, Director of the Boulder Laboratories. The first paper in the session was presented by W. R. Hewlett, (President, Institute of Radio Engineers). It contained an excellent summary of the contributions of radio engineering and radio physics to the communications field. The title, "Pulse Radio and Noise Radio," was chosen by Dr. Merle A. Tuve (Director, Department of Terrestrial Magnetism, Carnegie Institution of Washington) for his paper. This somewhat cryptic heading led to a delightful first-hand account of early ionospheric work, including the first experiments in proving the existence of the ionospheric

President Dwight D. Eisenhower enters the lobby of the new radio laboratory building of the NBS Boulder Laboratories, accompanied by (left to right) Governor Dan Thornton of Colorado; Dr. A. V. Astin, Director of the National Bureau of Standards; Dr. Frederick W. Brown, Director of the Boulder Laboratories; and Secretary of Commerce Sinclair Weeks. (Photo courtesy the Boulder (Colo.) Daily Camera.)

reflecting layers by use of the pulse technique. James C. W. Scott (Defence Research Board, Ottawa, Canada) spoke on "Problems of International Cooperation in Science", with an eloquent plea for increased freedom of exchange of ideas in science between nations so that the benefits of science might alleviate situations in backward countries. Dr. Walter O. Roberts (Director, High Altitude Observatory of Harvard University and University of Colorado) reviewed the experimental evidence of the emission of corpuscular radiation from the sun and advanced a theory to account for the terrestrial effects attributable to these particles. The closing invited paper of this session was delivered by Dr. C. H. Townes (Columbia University). He spoke on "The Confluence of Spectroscopy and Radio Engineering," referring to the remarkable application of atomic and molecular resonance to the precise control of radio frequency and thus to highly accurate time standards.

Three invited papers were given at other sessions. "The Early History of Radio Astronomy," by Dr. George C. Southworth (Bell Telephone Laboratories) was read by A. C. Beck at the start of the radio astronomy session Friday afternoon. Dr. Walter Gordy (Duke University) reviewed the development of the millimeter and submillimeter wave region of the spectrum during the final session on microwave techniques and applications; and Dr. Donald A. Menzel (Director, Harvard College Observatory) presented "On the Escape of Ionized Gases from the Sun" at a joint session on solar and upper atmosphere physics Wednesday afternoon.

In addition to the eight invited papers, a total of 75 contributed papers in nine different fields related to



radio were presented. The group of 21 papers on microwave techniques and applications was the largest and these papers were presented in four sessions presided over by Dr. Harold Lyons (NBS), Dr. Walter Gordy (Duke University), Dr. C. H. Townes (Columbia University), and Dr. W. C. DuVall (University of Colorado). Papers on tropospheric radio propagation totaled thirteen. The two sessions were presided over by John R. Gerhardt (University of Texas) and Harold Staras (Radio Corporation of America). Ten papers dealing with ionospheric radio propagation covered a wide range of subjects from geomagnetic oscillations at subaudio frequencies to the new very high frequency ionospheric transmission. The two sessions were presided over by A. G. McNish (NBS) and J. C. W. Scott (Defence Research Board, Ottawa). Dr. Walter O. Roberts (University of Colorado) was chairman of a joint session in solar and upper atmosphere physics during which six papers were given. This was the session headed by Dr. D. H. Menzel's invited paper. Six other papers in upper atmosphere physics comprised a very full session presided over by Dr. W. B. Pietenpol (University of Colorado). Atmospheric radio noise, which is of great interest from the communications viewpoint and also in the study of weather, was discussed from both viewpoints in six papers. Dr. Herbert L. Jones (Oklahoma A and M

College) gave an interesting account of the operation of the tornado warning service in Oklahoma. He also acted as session chairman.

The remaining sessions were in radio astronomy (four contributed papers), radio systems (five contributed papers), and high frequency and microwave standards (five contributed papers). The measurement of discrete radio sources at different wavelengths, the results of an experiment during the solar eclipse of June 1954, and the measurement of 21 cm galactic emission and absorption were included in the radio astronomy group, of which Dr. Donald H. Menzel was chairman. Dr. Richard C. Webb (Denver Research Institute) presided at the radio systems session which included a paper on the geodimeter, a new instrument which uses the velocity of a beam of light to measure distance, as in surveying. Other systems described were a signal transforming system, antenna tuning system, a television signal distribution system, and a system for measuring the harmonic power output of transmitters. Most of the papers in the session in high frequency and microwave standards dealt with the characteristics and applications of quartz crystals to frequency standards. In addition, a discussion of portable transfer standards for frequency was given. The Chairman was Dr. William A. Edson (Stanford University).

Publications of the National Bureau of Standards

Journal of Research of the National Bureau of Standards, volume 53, number 4, October 1954 (RP2533 to RP2543 incl.). Annual subscription \$4.00.

Journal of Research of the National Bureau of Standards, volume 52, Title page, corrections, and contents, January to June 1954 (RP2464 to RP2509, incl.). 10 cents.

Technical News Bulletin, volume 38, number 10, October 1954. 10 cents. Annual subscription \$1.00.

CRPL-121. Basic Radio Propagation Predictions for January 1955. Three months in advance. Issues October 1954. 10 cents. Annual subscription \$1.00.

RESEARCH PAPERS

Reprints from Journal of Research, volume 53, number 4, October 1954. Single copies of Research Papers are not available for sale. The Superintendent of Documents, U. S. Government Printing Office, Washington 25, D. C., will reprint 100 or more copies, and request for the purchase price should be mailed promptly to that office.

RP2533. Application of infrared spectroscopy to the determination of impurities in titanium tetrachloride. Rolf B. Johannesen, Charles L. Gordon, James E. Stewart, and Raleigh Gilchrist.

RP2534. Some properties of porcelains and phase relations in the ternary systems of beryllia and zirconia with titania, ceria, and chromia. S. M. Lang, R. S. Roth, and C. L. Fillmore.

RP2535. Effects of recent knowledge of atomic constants and of humidity on the calibrations of the National Bureau of Standards thermal-radiation standards. Ralph Stair and Russell G. Johnston.

RP2536. Synthesis of α -galactose-1- C^{14} and α -talose-1- C^{14} . Horace S. Isbell, Harriet L. Frush, and Nancy B. Holt.

RP2537. Determination of carbon-14 in solutions of C^{14} -labeled materials by means of a proportional counter. A. Schwebel, H. S. Isbell, and J. D. Moyer.

RP2538. Extension of the arc spectra of palladium and platinum (6500 to 12000 Å). Karl G. Kessler, William F. Meggers, and Charlotte E. Moore.

RP2539. Influence of molecular shape on the dielectric constant of polar liquids. F. Buckley and A. A. Maryott.

RP2540. Temperature dependence of compression of linear high polymers at high pressures. Charles E. Weir.

RP2541. Turbulent flow in shock tubes of varying cross section. Robert F. Dressler.

RP2542. Separation of titanium, tungsten, molybdenum, and niobium by anion exchange. John L. Hague, Eric D. Brown, and Harry A. Bright.

RP2543. Vapor pressure of nitrogen. George T. Armstrong.

CIRCULARS

C544. Formulas for computing capacitance and inductance. Chester Snow. 40 cents.

HANDBOOKS

H54. Protection against radiations from radium, cobalt-60, and cesium-137. 25 cents.

H57. Photographic dosimetry of X- and gamma rays. Margaret Ehrlich. 15 cents.

H58. Radioactive-waste disposal in the ocean. 20 cents.

APPLIED MATHEMATICS SERIES

AMS32. Table of sine and cosine integrals for arguments from 10 to 100. Reissue of MT13. \$2.25.

AMS34. Table of the gamma function for complex arguments. \$2.00.

PUBLICATIONS IN OTHER JOURNALS

Procedures used to improve the quality of ionospheric data. Sanford C. Gladden. Trans. Am. Geophys. Union (1530 P. Street, N. W., Washington 5, D. C.) 35, No. 3, 398 (June 1954).

The attenuation of gamma rays at oblique incidence. F. S. Kirn, R. J. Kennedy and H. O. Wyckoff. Radiology (713 East Genesee Street, Syracuse 2, New York) 63, No. 1, 94 (July 1954).

OFFICIAL BUSINESS



TECHNICAL NEWS BULLETIN

U. S. DEPARTMENT OF COMMERCE
SINCLAIR WEEKS, *Secretary*
NATIONAL BUREAU OF STANDARDS

A. V. ASTIN, *Director*

November 1954 Issued Monthly Vol. 38, No. 11

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NBS Publications (*continued*)

- Rheology of polyisobutylene. H. Low molecular weight polymers. Herbert Leaderman, Robert G. Smith and Robert W. Jones. *J. Polymer Sci.* (250 5th Avenue, New York 1, N. Y.) **14**, No. 73, 47 (July 1954).
- Chemical education in Switzerland. Roger G. Bates. *The Capital Chemist* (4801 Connecticut Avenue, Washington 8, D. C.) **4**, No. 5, 150 (May 1954).
- Research and standards for the plastics industry. Gordon M. Kline. *Modern Plastics* (575 Madison Avenue, New York 22, N. Y.) **31**, No. 12, 127 (August 1954).
- The location of the auroral absorption zone. Vaughn Agy. *J. Geophys. Res.* (The Johns Hopkins Press, Baltimore 18, Md.) **59**, No. 2, 267 (June 1954).
- Space charge wave amplification in a shock front and the fine structure of solar radio noise. Hari K. Sen. *Australian J. Phys.* (Australasian Medical Pub. Co. Ltd., Seamer and Arundel Streets, Glebe, Sydney) **7**, No. 1, 30 (1954).
- The concentration dependence of the sedimentation constants of flexible macromolecules. M. Wales and K. E. Van Holde. *J. Polymer Sci.* (250 5th Avenue, New York 1, N. Y.) **14**, No. 73, 81 (July 1954).
- Cellular concretes. Part 2. Physical Properties. Rudolph C. Valore, Jr. *J. Am. Concrete Inst.* (18263 W. McNichols Road, Detroit 19, Michigan) **25**, No. 10, 817 (June 1954). Preceding **50** (1954).
- Characteristic roots of quaternion matrices. Olga Taussky. *Archiv Der Mathematik* (Verlag Birkhauser, Basel Und Stuttgart) **5**, 99 (1954).
- Tables of the expected value of $1/X$ for positive Bernoulli and Poisson variables. Edwin L. Grab and I. Richard Savage. *J. Am. Stat. Assoc.* (c/o W. Allen Wallace, University of Chicago, Illinois) **49**, 169 (March 1954).
- The effect of preheating on thermal expansion of silica-gypsum investments. G. F. Glasson, W. T. Sweeney, and I. C. Schoonover. *J. Am. Dental Assoc.* (222 East Superior Street, Chicago, Illinois) **48**, 433 (April 1954).

Summary of AIEE-IRE-ACM conference. Allen V. Astin. *Proc. Eastern Joint Computer Conf.* (Published by AIEE, 33 West Thirty-ninth Street, New York 18, N. Y.) p. 116 (December 8-10, 1953).

A study of some operations involved in cement analysis. Leonard Bean and Ethel J. Hackney. *ASTM Bull.* (1916 Race Street, Philadelphia 3, Pennsylvania) No. 197 (TP71) 43, (April 1954).

The backscattering of the Co^{60} gamma rays from infinite media. Evans Hayward and John H. Hubbell. *J. Appl. Phys.* (57 East Fifty-fifth Street, New York 22, New York) **25**, No. 4, 506 (April 1954).

Publications for which a price is indicated are available only from the Superintendent of Documents, U. S. Government Printing Office, Washington 25, D. C. (foreign postage, one-third additional). Reprints from outside journals are not available from the National Bureau of Standards but can often be obtained from the publishers.

PATENTS

(The following U. S. Patents have been granted to NBS inventors.)

- No. 2,682,747. July 6, 1954. Combined fuel injector and flame stabilizer. Fillmer W. Ruegg. Assigned to the United States of America as represented by the Secretary of the Navy.
- No. 2,690,376. September 28, 1954. Recovery of pure uranium compounds from ores. James I. Hoffman. Assigned to the United States of America as represented by the United States Atomic Energy Commission.
- No. 2,690,469. September 28, 1954. Flexible, low-noise, electrical cable. Thomas A. Perls. Assigned to the United States of America as represented by the Secretary of Commerce.

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